Appendix C

Calibration Records

Appendix C

GTS Duratek Calibration Records

Calibration certificates supplied by GTS Duratek and associated with the GTS Duratek calibration records contained in the main body of this document are reproduced in this appendix.

Certificate of Calibration
RLSM10.0
November 19, 1999

Data were taken in the Moisture models on November 19, 1999 for RLSM10.0 neutron-neutron moisture tool. This calibration is the first calibration for this instrument at the Hanford site.

Six models were used for moisture calibration, 3 for 6"casing and 3 for 8" casing. Repeated spectra were recorded for each model in order to perform statistical analysis. The observed statistical variation agreed with the theoretically predicted variation, refer to the file AveOut.XLS for this analysis.

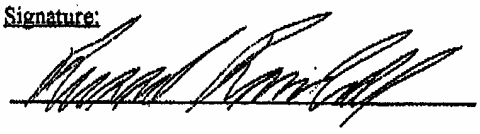
The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s).

6" casing	8" casing
a = .0001303	a = .00005348
α = 2.232	α = 2.551

The undersigned certifies that the data archived in data file "MST10-0_11-19-99.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-306, "Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration" and that the above stated calibration coefficients are correct and applicable for tool RLSM10.0 effective November 19, 1999.

Signature: 

Date: November 30, 1999

Company:

Three Rivers Scientific

Certificate of Calibration for
Instrument RLSM10.0 on
Logging Unit INEEL Van

August 28, 2000

Data were taken in the Moisture models on August 28, 2000 for RLSM10.0 neutron-neutron moisture tool, on logging unit INEEL van.

Six models were used for moisture calibration, 3 for 6"casing and 3 for 8" casing. Repeated spectra were recorded for each model in order to perform statistical analysis. The observed statistical variation agreed with the theoretically predicted variation, refer to the file Moist.XLS for this analysis.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

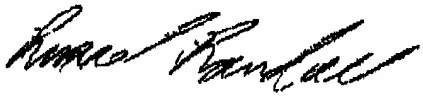
$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s).

6" casing	8" casing
a = .0001574	a = .00005562
α = 2.194	α = 2.541

The undersigned certifies that the data archived in file "MST00-0_8-28-00.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-306, "Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration" and that the above stated calibration coefficients are correct and applicable for tool RLSM10.0, on logging unit INEEL van, effective August 28, 2000.

Signature: Date:



September 3, 2000

Russel Randall, PhD

Moisture Calibration Extrapolation to 5.5 Inch Borehole
Instrument RLSM10.0 on
Logging Unit INEEL Van

August 28, 2000

Moisture calibration was performed in the Hanford physical models. These standards have 6 and 8 inch ID casings. The Pit 9 borehole is cased with a 4.5 inch ID iron casing. The calibration for the moisture response is a function of borehole diameter.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

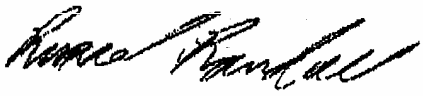
$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s). A linear extrapolation was applied to determine the 5.5 inch borehole diameter.

5.5" borehole
a = .0002023
α = 2.096

The undersigned certifies that the basic calibration was evaluated in accordance with WMTS procedures and that the above stated calibration coefficients are correct and applicable for tool RLSM10.0, on logging unit INEEL van, effective August 28, 2000. The analysis files are archived in the file "MST00-0_8-28-00.zip".

Signature: Date:



September 3, 2000

Russel Randall, PhD

Moisture Calibration Extrapolation to 5.5 Inch Borehole
Instrument RLSM10.0 on
Logging Unit RLS2
August 22, 2000

Moisture calibration was performed in the Hanford physical models. These standards have 6 and 8 inch ID casings. The Pit 9 borehole is cased with a 4.5 inch ID iron casing. The calibration for the moisture response is a function of borehole diameter.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

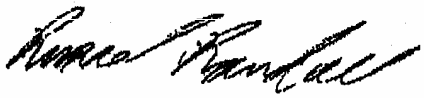
$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s). A linear extrapolation was applied to determine the 5.5 inch borehole diameter.

5.5" borehole
a = .0001650
α = 2.134

The undersigned certifies that the basic calibration was evaluated in accordance with WMTS procedures and that the above stated calibration coefficients are correct and applicable for tool RLSM10.0, on logging unit RLS2, effective August 22, 2000. The analysis files are archived in the file "MST00-0_8-22-00.zip".

Signature: Date:



September 3, 2000

Russel Randall, PhD

Certificate of Calibration for
Instrument RLSM10.0 on
Logging Unit RLS2

August 22, 2000

Data were taken in the Moisture models on August 21 & 22, 2000 for RLSM10.0 neutron-neutron moisture tool, on logging unit RLS2. This calibration is required for the logging unit modifications.

Six models were used for moisture calibration, 3 for 6"casing and 3 for 8" casing. Repeated spectra were recorded for each model in order to perform statistical analysis. The observed statistical variation agreed with the theoretically predicted variation, refer to the file Moist.XLS for this analysis.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

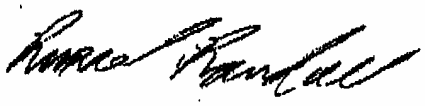
$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s).

6" casing	8" casing
a = .0001368	a = .00006126
α = 2.221	α = 2.521

The undersigned certifies that the data archived in data file "MST00-0_8-22-00.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-306, "Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration" and that the above stated calibration coefficients are correct and applicable for tool RLSM10.0, on logging unit RLS2 effective August 22, 2000.

Signature: Date:



September 3, 2000

Russel Randall, PhD

Certificate of Calibration
RLSM00.0
May 13, 1999

Data were taken at the Pasco models on May 13, 1999 for RLSM00.0 neutron-neutron moisture tool. There is no change in the version, since no instrument changes have occurred during the time from previous calibration. This calibration is the required yearly quality performance.

Six models were used for moisture calibration, 3 for 6"casing and 3 for 8" casing. Repeated spectra were recorded for each model in order to perform statistical analysis. The observed statistical variation agreed with the theoretically predicted variation, refer to the file Stats.XLS for this analysis.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s).

6" casing	**8" casing**
a = .0000490	**a = .00001597**
α = 2.206	**α = 2.537**

The undersigned certifies that the data archived in data file "MST3-1_5-13-99.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-306, "Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration" and that the above stated calibration coefficients are correct and applicable for tool RLSM00.0 effective May 13, 1999.

Signature: _____ Date: May 17, 1999

Company:

Three Rivers Scientific

Calibration for
Instrument RLSG035A00S00.0 on
Logging Unit INEEL Van
August 24, 2000

Data were collected at the Hanford models on August 24, 2000 for instrument RLSG035A00S00.0, on logging unit INEEL van. Four models were used, the thorium, uranium, potassium, and mix models, SBT SBU, SBK, and SBM at Hanford. Gain factor of 4 data were collected in the SBT and SBU models. Ten spectra of 500 sec real time were recorded. Calibration data analysis was performed as specified by "Calibration of the Radionuclide Logging System Germanium Detector," WHC-SD-EN-TI-292.
Use of efficiency function is defined by:

$$C = \frac{1}{\varepsilon(E)} \bullet \frac{P}{N}$$

where C is the isotope concentration in pCi/g, P is the fully corrected photo peak count rate in cts/sec, N is the absolute gamma ray intensity per 100 decays for the selected photo peak, and ε(E) is the instrumentation efficiency function for gamma ray energy E (in keV).

The form of the efficiency function is:

$$\varepsilon(E) = \frac{1}{a \cdot E^{\alpha} + b \cdot E^{\beta}}$$

a, α, b, and β are the resulting coefficients determined by the calibration procedure. The present values for this instrument are:

a = 8.385
α = .238
b = $1.01*10^{10}$
β = -4.301

Energy limits are between 75 and 3000 keV.
Special case consideration must be given to analysis of energies below 300 keV, due to photoelectric effects in unknown formation conditions.

The undersigned certifies that the data archived in data file "RLSG8-24-00.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-292, "Calibration of the Radionuclide Logging System Germanium Detector" and that the above stated calibration coefficients are correct and applicable for tool RLSG035A00S00.0, on logging unit INEEL van, effective August 24, 2000.

Name Russel Randall, PhD Date September 3, 2000

Signature

Calibration for RLSG3.2
January 19, 1999

Data were collected at the Hanford models on January 19, 1999 for instrument RLSG version 3.2. Two models were used, the thorium and the uranium models, SBT & SBU at Hanford. No gain factor of 4 data were collected. Ten spectra of 500 sec real time were recorded. Calibration data analysis was performed as specified by "Calibration of the Radionuclide Logging System Germanium Detector," WHC-SD-EN-TI-292. Operational configuration is changed to the long dual detector housing and thus the designation of version 2. The calibration is valid for Truck #2.

Use of efficiency function is defined by:

$$C = \frac{1}{\varepsilon(E)} \bullet \frac{P}{N}$$

where C is the isotope concentration in pCi/g, P is the fully corrected photo peak count rate in cts/sec, N is the absolute gamma ray intensity per 100 decays for the selected photo peak, and ε(E) is the instrumentation efficiency function for gamma ray energy E (in keV).

The form of the efficiency function is:

$$\varepsilon(E) = \frac{1}{a \cdot E^{\alpha} + b \cdot E^{\beta}}$$

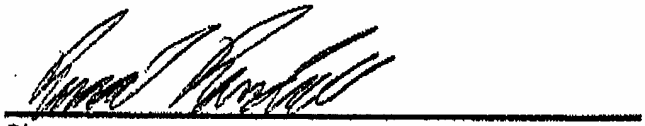
a, α, b, and β are the resulting coefficients determined by the calibration procedure. The present values for this instrument are:

a = 11.51
α = .1930
b = 0
β = 0

Energy limits are between 150 and 3000 keV.
Special case consideration must be given to analysis of energies below 150 keV.

The undersigned certifies that the data archived in data file "RLSG3-2-99.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-292, "Calibration of the Radionuclide Logging System Germanium Detector" and that the above stated calibration coefficients are correct and applicable for tool RLSG3.2 effective January 19, 1999.

Name Russel Randall, PhD Date January 23, 1999



Signature

Calibration for RLSG020NS00N00.0
January 7, 2000

Data were collected at the Hanford models on January 7, 2000 for instrument RLSG020NS00N00.0. The high Chlorine model was used to collect 10 spectra of 600 sec real time. Calibration data analysis was performed for the specific Cl line at 1165 keV. MCNP was used to extrapolate the calibration in this physical model to the standard conditions representing the clean environment of Pit 9 conditions.

The concentration is defined by:

$$C_{cl} = \alpha_{cl} \cdot P_{cl} \cdot f(bh, \Sigma, \rho, moisture)$$

where C_{cl} is the isotope concentration in parts per million by weight (ppm), P is the fully corrected photo peak count rate in c/s, α_{cl} is the calibration fit coefficient, f(bh, Σ, ρ, moisture) is the combined extrapolation factor for borehole size, capture cross section, formation density, and formation moisture content based upon MCNP computations from the physical model to pit 9 conditions.

The logging conditions for the two conditions are:

	Physical model	Pit 9
Borehole size:	6.0 inch	5.5 inch
High cross section elements:	1.4 wt% Cl	50 ppm B
Formation density	2.0 g/cm^3	1.8 g/cm^3
Moisture	23 % (by volume)	7 % (by volume)

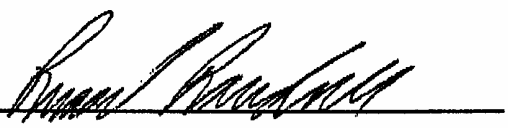
The calibration coefficients are:

Photo peak	α_{cl}	f(bh, Σ, ρ, moisture)
Cl-1165	2.20E+3	0.364

α_{cl} has units of ppm Cl per c/s.

The undersigned certifies that the data archived in data file "RLSNG2-1-2000.zip" were collected and evaluated in accordance with rigorous scientific principles and that the above stated calibration coefficients are correct and applicable for tool RLSG020NS00N00.0 effective January 7, 2000.

Name Russel Randall, PhD Date January 19, 2000

Signature 

Calibration for RLSG018NS00N00.0
February 22, 1999

Data were collected at the Hanford models on February 22, 1999 for instrument RLSG018NS00N00.0. The high Chlorine model was used to collect 10 spectra of 300 sec real time. Calibration data analysis was performed for the specified three Cl lines at 1165, 1951, and 1959 keV. MCNP was used to extrapolate the calibration in this physical model to the standard conditions representing the clean environment of Pit 9 conditions.

The concentration is defined by:

$$C_{cl}=\alpha_{cl}\cdot P_{cl}\cdot f(bh,\Sigma,\rho,moisture)$$

where C_{cl} is the isotope concentration in parts per million by weight (ppm), P is the fully corrected photo peak count rate in c/s, α_{cl} is the calibration fit coefficient, f(bh, Σ, ρ, moisture) is the combined extrapolation factor for borehole size, capture cross section, formation density, and formation moisture content based upon MCNP computations from the physical model to pit 9 conditions.

The logging conditions for the two conditions are:

	Physical model	Pit 9
Borehole size:	6.0 inch	5.5 inch
High cross section elements:	1.4 wt% Cl	50 ppm B
Formation density	2.0 g/cm^3	1.8 g/cm^3
Moisture	23 % (by volume)	7 % (by volume)

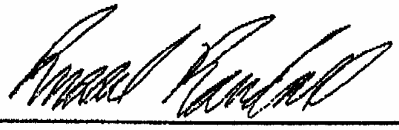
The calibration coefficients for the three photo peaks are:

Photo peak	α_{cl}	f(bh, Σ, ρ, moisture)
Cl-1165	2.19E+3	0.364
Cl-1951	5.15E+3	0.367
Cl-1959	6.73E+3	0.367

α_{cl} has units of ppm Cl per c/s.

The undersigned certifies that the data archived in data file "RLSNG2-0-99.zip" were collected and evaluated in accordance with rigorous scientific principles and that the above stated calibration coefficients are correct and applicable for tool RLSG018NS00N00.0 effective February 17, 1999.

Name Russel Randall, PhD Date March 10, 1999

Signature 

Certificate of Calibration for
Instrument RLSG020NS00N00.0
Logging Unit RLS2
August 29, 2000

Data were collected at the Hanford models on August 25-29, 2000 for instrument RLSG020NS00N00.0 on logging unit RLS2. The saltwater tank was used to collect spectra of 500 sec real time for stages of NaCl mixture. The repeat number of spectra varied, but was 10 or more for each mixed concentration. Just after salt addition, and during the stirring action, spectra were recorded in order to view the action of mixing. Calibration data analysis was performed for the specified Cl line at 1165 keV.

The concentration is defined by:

$$C_{cl}=\alpha \cdot \ln\left[\frac{1}{1-\frac{P}{a}}\right]$$

where C_{cl} is the chlorine concentration in weight percent (wt%), P is the dead time corrected photo peak count rate in c/s, and parameters α and a are calibration fit coefficients.

Logging specification for the physical conditions is:

Borehole:	6.5 inch OD iron casing 5.5 inch ID
High cross section elements:	0-23 wt% Cl
Formation density	0.998 - 1.175 g/cm^3
Water partial density	0.998 - 0.9025 g/cm^3

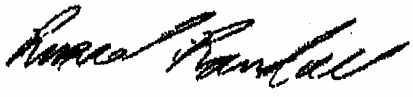
The calibration coefficients for the 1165 keV photo peak are:

α_{cl}	a
9.02	12.39

α_{cl} has units of wt% Cl and a has units of (c/s)$^{-1}$.

The undersigned certifies that the data archived in data file "RLSNG8-29-00.zip" were collected and evaluated in accordance with rigorous scientific principles and that the above stated calibration coefficients are correct and applicable for tool RLSG020NS00N00.0 effective August 29, 2000. The methodology of the analysis is documented in the article entitled "Saltwater Calibration for the Neutron Induced Gamma Logging System".

Name Russel Randall, Ph.D. Date September 7, 2000



Signature